

RECEIVER CIRCUIT

BACKGROUND OF THE INVENTION

The present invention relates to a receiver circuit, and more particularly, it relates
5 to a receiver circuit suitably used for detecting, with low power consumption, a cable
having come off in a data transfer system using the cable.

In general, in a data transfer system using a cable such as LVDS (Low Voltage
Differential Signaling), a receiver circuit should have a function to detect a cable having
come off and to fix the data output to a HIGH or LOW level in accordance with the current
10 status of the system, and this function is designated as a fail safe function.

A conventional receiver circuit for realizing the fail safe function is shown in FIG.
6. This receiver circuit includes a data processing unit **1000** and a clock processing unit
2000.

The data processing unit **1000** includes an input buffer **1** and a 1:7 serial-parallel
15 converter circuit **2** for converting a serial output signal **RDATA** of the input buffer **1** into
parallel data in 7-bit groups and outputting the parallel data. A terminating resistor **RT1**
is connected between positive and negative input terminals **RDP** and **RDM** of the input
buffer **1** for accepting differential data signals with small amplitude, a pull-up resistor **RP1**
is connected between the positive input terminal **RDP** and a power source **VDD**, and a
20 pull-down resistor **RP2** is connected between the negative input terminal **RDM** and a
power source **VSS**.

The clock processing unit **2000** includes an input buffer **3** and a multiphase PLL
circuit **4** for controlling the frequency and the phase of an output signal **RCLOCK** of the
input buffer **3**. The positive and negative input terminals **INP** and **INM** of the input
25 buffer **3** for accepting differential clock signals with small amplitude are connected to a

terminating resistor **RT2**, a pull-up resistor **RP3** and a pull-down resistor **RP4** in the same manner as in the input buffer **1** of the data processing unit **1000**.

In this receiver circuit, the pull-up resistors **RP1** and **RP3** and the pull-down resistors **RP2** and **RP4** are used for realizing the fail safe function. When a cable has 5 come off and is disconnected, for example, in the data processing unit **1000**, a current passes through the three resistors, namely, the pull-up resistor **RP1**, the terminating resistor **RT1** and the pull-down resistor **RP2**, and IR drop occurring in the terminating resistor **RT1** is detected by the input buffer **1**, so that the output level of the 1:7 serial-parallel converter circuit **2** can be fixed to a HIGH or LOW level. In this case, the terminating 10 resistor **RT1** is set to 100Ω according to the LVDS standard.

In assuming, for example, that $RP1 = RP2 = 20 \text{ k}\Omega$, $RT1 = 100 \Omega$, $VDD = 3.3 \text{ V}$ and $VSS = 0 \text{ V}$, a current, $3.3\text{V}/40.1 \text{ k}\Omega = 82 \text{ uA}$, passes through the three resistors **RP1**, **RT1** and **RP2**, and hence, a potential difference, $82 \text{ uA} \times 100 \Omega = 8.2 \text{ mV}$, is caused in the terminating resistor **RT1**.

15 In the aforementioned conventional architecture, however, even in the case where the cable is normally connected and hence the fail safe function is not exhibited, a current steadily passes through the pull-up resistor **RP1**, the terminating resistor **RT1** and the pull-down resistor **RP2**, which wastefully consumes power. In particular, when the number of data channels (i.e., the number of data processing units) is increased, the steady-state 20 current increases in proportion to the number of data channels, and therefore, the wasteful power consumption is further increased.

In order to overcome this problem, when, for example, the pull-up resistor **RP1** and the pull-down resistor **RP2** are set to a larger value for reducing the current consumption, although the steady-state current passing through these resistors can be 25 reduced, voltage drop caused in the terminating resistor **RT1** is also reduced, resulting in

increasing possibility of error detection of noise on the input data line.

As a result, noise resistance is lowered when the fail safe function is exhibited. Thus, the conventional architecture is not preferable.

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SUMMARY OF THE INVENTION

The present invention was devised to overcome the aforementioned conventional problem, and an object of the invention is, in a receiver circuit, detecting, with low power consumption, a state where a cable has come off and is disconnected.

In order to achieve the object, according to the invention, the pull-up resistors and 10 the pull-down resistors are removed from the data signal input terminal and the clock input terminal, and the number of transitions or the amplitude of a data signal or a clock signal is detected, so that the state where a cable has come off can be detected on the basis of the number of transitions or the amplitude.

Specifically, the receiver circuit of this invention for receiving a receive signal 15 that undergoes a given number or more transitions in a given time, includes a processing unit for processing the receive signal; and a signal detection unit that accepts the receive signal, includes a transition number detection circuit for detecting a number of transitions of a signal obtained based on the receive signal and outputs a signal for controlling an operation of the processing unit when the number of transitions detected by the transition 20 number detection circuit is not more than a set value.

Alternatively, the receiver circuit of this invention for receiving a receive signal that undergoes a given number or more transitions in a given time, includes a processing unit for processing the receive signal; and a signal detection unit that accepts the receive signal, includes an amplitude detection circuit for detecting amplitude of the receive signal 25 and outputs a signal for controlling an operation of the processing unit when the amplitude

detected by the amplitude detection circuit is not more than a set value.

In one aspect of the receiver circuit of this invention, the receive signal is a data signal or a clock signal.

In another aspect of the receiver circuit of this invention, the receive signal is a data signal and a clock signal received through a cable in which a plurality of transfer paths are integrated, and one of the data signal and the clock signal is input to the signal detection unit.

In one aspect of the receiver circuit of this invention, the amplitude detection circuit includes an offset buffer that accepts the receive signal and outputs a HIGH or LOW signal when the amplitude of the receive signal is not more than a set value.

In one aspect of the receiver circuit of this invention, the signal detection unit includes a set value change circuit for changing the set value of the offset buffer.

In one aspect of the receiver circuit of this invention, the set value is changed by the set value change circuit on the basis of data stored in an externally readable and writable resistor.

In another aspect, the receiver circuit of this invention further includes an offset buffer that accepts the receive signal and outputs a HIGH or LOW signal when amplitude of the receive signal is not more than a set value, and the HIGH or LOW signal output by the offset buffer is input to the transition number detection circuit as the signal obtained based on the receive signal.

In one aspect of the receiver circuit of this invention, the processing unit is a data processing unit for processing a data signal received as the receive signal and is reset in accordance with the signal output by the signal detection unit.

In another aspect of the receiver circuit of this invention, the processing unit is a data processing unit for processing a data signal received as the receive signal and is

power-down operated in accordance with the signal output by the signal detection unit.

Therefore, according to the invention, in the state where a cable has come off, the number of transitions or the amplitude of the receive signal detected in the signal detection unit is not more than the set value, and therefore, the signal is output from the signal detection unit to the data processing unit, so as to control the data processing unit.

Accordingly, there is no need to provide a pull-up resistor and a pull-down resistor that are conventionally provided to the input terminals of a receiver circuit for realizing the fail safe function, and hence, the area of the receiver circuit can be reduced. In addition, the present receiver circuit can be free from a steady-state current conventionally consumed through these resistors, and therefore, the disconnection state where a cable has come off can be detected with low power consumption. In particular, in a system having a large number of data channels, the steady-state current can be reduced with respect to each channel, resulting in reducing the power consumption in the whole circuit and the whole system.

Also, in this invention, the transfer paths for the data signal and the clock signal to be input to the signal detection unit are integrated in one cable, and therefore, the disconnection state of the cable can be definitely detected by detecting the number of transitions or the amplitude of merely one of these signals. Accordingly, in the case where the number of transitions or the like of the clock signal is detected, there is no need to restrict the number of transitions of the data signal.

Furthermore, according to the invention, in the case where the cable has come off and hence the line for the receive signal is placed in a high-impedance state, even when noise appears on this signal line, the output signal of the offset buffer can be fixed to HIGH or LOW level because the amplitude of the noise is not more than the set value.

Accordingly, identification of noise as error in detecting the disconnection state of the

cable can be avoided. Thus, the fail safe function can be realized while attaining both the improvement of the noise resistance and the low power consumption.

Moreover, according to the invention, the set value of the offset buffer can be changed by the set value change circuit. Therefore, the noise resistance can be changed
5 by changing the level for detecting noise in accordance with the amplitude of noise varied depending upon an employed application, and thus, the degree of freedom in design can be increased.

According to the invention, in the state where the cable has come off, the number of transitions of the receive signal is generally not more than the set value, and hence, the
10 operation of the data processing unit is controlled by the signal detection unit. Even when noise is caused in the signal detection unit, the number of transitions of the noise is not more than the set value and hence the output of the offset buffer is fixed to HIGH or LOW level. Therefore, the number of transitions of the signal input to the transition number
15 detection circuit can be definitely not more than the set value, so that a normal fail safe function can be always realized.

Furthermore, according to the invention, when there arises a disconnection state where the cable has come off, the data processing unit is reset in accordance with the signal output from the signal detection unit. Accordingly, all outputs from the data processing unit can be fixed to LOW or HIGH level. Therefore, for example, in a
20 transmitter/receiver system for video signals, if there arises a disconnection state where a cable has come off, the displayed image is in a single color, and hence, a user can easily visually find that the cable has come off.

Moreover, according to the invention, when there arises a disconnection state where the cable has come off, the data processing unit is power-down operated in
25 accordance with the signal output from the signal detection unit. Accordingly, a current

passing in the disconnection state where the cable has come off can be controlled, so as to realize low power consumption and power control when the fail safe function is exhibited.

BRIEF DESCRIPTION OF THE DRAWINGS

5 FIG. 1 is a circuit diagram of a receiver circuit according to Embodiment 1 of the invention;

FIG. 2 is a timing chart of the receiver circuit of FIG. 1;

FIG. 3 is a circuit diagram of a receiver circuit according to Embodiment 2 of the invention;

10 FIG. 4 is a circuit diagram of a receiver circuit according to Embodiment 3 of the invention;

FIG. 5 is a circuit diagram of a receiver circuit according to Embodiment 4 of the invention; and

FIG. 6 is a circuit diagram of a conventional receiver circuit.

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DETAILED DESCRIPTION OF THE INVENTION

Receiver circuits according to preferred embodiments of the invention will now be described with reference to the accompanying drawings.

EMBODIMENT 1

20 FIG. 1 is a circuit diagram of a receiver circuit according to Embodiment 1 of the invention. This receiver circuit includes a data processing unit (processing unit) 100, a clock processing unit (processing unit) 200 and a signal detection unit 300.

The data processing unit 100 includes an input buffer 1 and a 1:7 serial-parallel converter circuit 2. This data processing unit 100 accepts, at the input buffer 1, 25 differential data signals with small amplitude received at small amplitude differential data

input terminals **RDP** and **RDM** of the receiver circuit (which signals are hereinafter referred to as the data input signals **RDP** and **RDM**), converts the data input signals into a signal at a CMOS amplitude level, for example, into a serial data signal **RDATA** with amplitude of 3.3 V, and outputs the serial data signal. A terminating resistor **RT1** is 5 connected between two input terminals **INP** and **INM** of the input buffer **1**. In this embodiment, the terminating resistance is, for example, 100 Ω , and the differential data signals **RDP/M** with the small amplitude are, for example, signals of a frequency of 595 Mbps and amplitude of 1.2 V \pm 200 mV as shown in FIG. 2. The output terminal of the input buffer **1** is connected to a SDIN terminal of the 1:7 serial-parallel converter circuit 2 for converting the serial data signal **RDATA** output from the input buffer **1** into parallel data. In this case, the data transfer rate per second of the serial data signal **RDATA** is 10 expressed as 595 Mbps \times 1 bit. The converted parallel data signal is output from an output terminal **PDO**UT of the 1:7 serial-parallel converter circuit **2** to an output terminal **RD[0:6]** of the receiver circuit. At this point, the data transfer rate per second is 15 expressed as 85 Mbps \times 7 bits.

The clock processing unit **200** includes an input buffer **3** and a multiphase PLL circuit **4**. This clock processing unit **200** accepts, at the input buffer **3**, differential clock signals with small amplitude received from small amplitude differential clock input terminals **RCKP** and **RCKM** of the receiver circuit (which signals are hereinafter referred to as the clock input signals **RCKP** and **RCKM**) and outputs an output signal **RCLOCK**. A terminating resistor **RT2** is connected between the two input terminals **INP** and **INM** of the input buffer **3**. In this embodiment, the terminating resistance is, for example, 100 Ω , and the clock input signals **RCKP/M** are, for example, signals of a frequency of 85 MHz 20 and amplitude of 1.2 V \pm 200 mV as shown in FIG. 2. The output signal **RCLOCK** and amplitude of 1.2 V \pm 200 mV as shown in FIG. 2. The output signal **RCLOCK** 25 output from the input buffer **3** is input to an input terminal **REFCK** of the multiphase PLL

circuit 4 for adjusting the frequency and the phase thereof. Then, a clock signal **LCK** whose frequency and phase have been adjusted by the multiphase PLL circuit 4 is output from an output terminal **CKOUT**. This clock signal **LCK** is input to a clock input terminal **CK** of the 1:7 serial-parallel converter circuit 2 in order to obtain synchronization 5 with a sender side in the serial-parallel conversion of the data signal in the 1:7 serial-parallel converter circuit 2 of the data processing unit 100.

The signal detection unit 300 includes a frequency detection circuit (transition number detection circuit) 5. The input terminal **CKIN** of the frequency detection circuit 5 is supplied with the output signal **RCLOCK** of the input buffer 3 of the clock processing 10 unit 200, so that the number of transitions of the signal **RCLOCK** occurring within a predetermined time can be detected in the frequency detection circuit 5. When the number of transitions is not more than a predetermined set value, a reset signal **NRESET** is output from the output terminal **SD**. This reset signal **NRESET** is input to a reset signal input terminal **NR** of the 1:7 serial-parallel converter circuit 2 of the data processing 15 unit 100, so as to reset the output of the data signal received by the receiver circuit. When, however, the number of transitions of the signal **RCLOCK** detected within the predetermined time exceeds the set value, the reset signal is not output, and hence, the operation of the data processing unit 100 is not disturbed.

Now, the operation of the receiver circuit of this embodiment will be described. 20 First, in the case where the frequency of the input signal **CKIN** of the frequency detection circuit 5 is 20 kHz or more, namely, in the case where a cable is connected to the clock input terminals **RCKP/M** for inputting the clock signals, the output terminal **SD** of the frequency detection circuit 5 is at H level (**SD = H**), and therefore, the reset signal input terminal **NR** of the 1:7 serial-parallel converter circuit 2 is at H level, so that the 1:7 serial- 25 parallel converter circuit 2 can be normally operated.

In contrast, in the case where the frequency of the input signal **CKIN** of the frequency detection circuit **5** is not more than 20 kHz, namely, the cable has come off and is disconnected, the output terminal **SD** of the frequency detection circuit **5** is at L level (**SD** = L), and therefore, the reset signal input terminal **NR** of the 1:7 serial-parallel converter circuit **2** is at L level. Accordingly, the reset signal is input to the 1:7 serial-parallel converter circuit **2**, and hence, the output data **RD[0:6]** is fixed to L level, so as to realize the fail safe function.

Accordingly, in this embodiment, there is no need to provide the pull-up resistors and the pull-down resistors that are conventionally provided in the data processing unit and the clock processing unit, and since the fail safe function can be thus realized with a simple architecture, area reduction and low power consumption can be both attained. Also, since a consumed current necessary for realizing the fail safe function can be reduced, the power consumption of the whole system can be reduced. In particular, when the system has a large number of data channels, the effect to reduce the power consumption is remarkably exhibited.

In the receiver circuit of this embodiment, in the case where the data signals and the clock signals are input, the signal **RCLOCK** obtained based on the clock signals is input to the signal detection unit **300**. Instead, the signal **RDATA** obtained based on the data signals alone may be input to the signal detection unit **300**. Alternatively, needless to say, in the case where the data signals alone are received, the data signals may be input to be detected in the signal detection unit **300**.

Also, in this embodiment, the reset signal to be output to the data processing unit **100** is controlled on the basis of the number of transitions of the signal detected in the signal detection unit **300**, so as to restrict (control to reset) the operation of the data processing unit **100**. In the case where the data processing unit **100** has a power down

signal input terminal, the output signal from the signal detection unit **300** can be input as a power down signal to the power down signal input terminal so as to power-down control the operation of the data processing unit **100**.

EMBODIMENT 2

5 A receiver circuit according to Embodiment 2 of the invention will now be described with reference to FIG. 3. In this embodiment, in the case where a cable has come off and hence clock input signals **RCKP/M** are placed in a high-impedance state (i.e., Hi-Z state), even when noise appears on the clock signal input lines **RCKP/M**, the noise is prevented from being detected as a signal in error. In this embodiment, like reference 10 numerals are used to refer to like elements used in Embodiment 1 so as to omit the description.

The receiver circuit of FIG. 3 includes a data processing unit **100**, a clock processing unit **200** and a signal detection unit **400**.

15 The receiver circuit of this embodiment is different from that of Embodiment 1 shown in FIG. 1 in the configuration of the signal detection unit. Specifically, although the signal detection unit **300** of the receiver circuit of FIG. 1 includes the frequency detection circuit **5** alone, the signal detection unit **400** of this receiver circuit additionally includes an offset buffer **6** and a bias generation circuit **7**.

20 In the signal detection unit **400** of FIG. 3, in order to detect the number of transitions occurring within a predetermined time in the frequency detection circuit **5**, clock input signals **RCKP/M** received by the offset buffer **6** are first converted into a single signal **RSIG** of a CMOS amplitude level by the offset buffer **6**. At this point, the offset buffer **6** receives bias voltages **BIASP** and **BIASM** output by the bias generation circuit **7** and compares a set value **Vth** (which is also designated as an offset value) defined 25 as $Vth = |BIASP - BIASM|$ with the amplitude of the signal **RSIG**. When the amplitude

of the signal **RSIG** is not more than the set value **Vth**, the offset buffer **6** fixes the output signal **RSIG** to LOW level or HIGH level and outputs the fixed LOW or HIGH level signal. In contrast, when the amplitude exceeds the set value **Vth**, the offset buffer **6** directly outputs the clock input signal **RCKP/M** as the output signal **RSIG**. This output signal **RSIG** is input to the frequency detection circuit **5**.

In this embodiment, the set value **Vth** is set to, for example, 50 mV. Also, the bias generation circuit **7** is a circuit that can easily generate a bias voltage through resistance potential division, and the values of the bias voltages **BIASP** and **BIASM** are, for example, 1.225 V (= 1.2 V + 25 mV) and 1.175 V (= 1.2 V - 25 mV), respectively.

In this manner, in the case where the signal detection unit **400** includes the offset buffer **6** and the frequency detection circuit **5**, even if noise appears when the cable has come off and the clock input terminals **RCKP/M** are placed in the Hi-Z state, the fail safe function can be normally realized without error detection of the noise. Accordingly, the fail safe function can be realized while attaining both of the improvement of the noise resistance and the low power consumption.

Also in this embodiment, the operation for resetting the data processing unit **100** is controlled on the basis of the number of transitions of the output signal **RSIG** of the offset buffer **6** occurring in the predetermined time in the signal detection unit **400**. Instead, in the case where the data processing unit **100** has a power down signal input terminal, a power down signal can be input to this power down signal input terminal, so as to power-down control the data processing unit **100**.

EMBODIMENT 3

FIG. 4 shows a receiver circuit of Embodiment 3 of the invention.

This receiver circuit includes a data processing unit **100**, a clock processing unit **200** and a signal detection unit **500**. This receiver circuit is different from the receiver

circuit of Embodiment 2 shown in FIG. 3 in the configuration of the signal detection unit. Specifically, the signal detection unit 500 of this embodiment is obtained by additionally providing, to the signal detection unit 400 of FIG. 3, a bias selection circuit (set value change circuit) 8 having a set value change terminal SEL for changing the set value V_{th} of 5 the offset buffer 6.

The bias selection circuit 8 is connected to the bias generation circuit 7, receives a plurality of different bias voltages output by the bias generation circuit 8 and outputs two of these plural bias voltages to bias voltage input terminals **BP** and **BM** of the offset buffer 6. At this point, the two bias voltages output by the bias selection circuit 8 are selected on 10 the basis of a signal input to the set value change terminal SEL. It is noted that the offset buffer 6 and the frequency detection circuit 5 of the signal detection unit 500 have the same configurations and the same functions as those of the signal detection unit 400 of the receiver circuit of Embodiment 2 shown in FIG. 3.

In this embodiment, the bias generation circuit 7 outputs four different bias 15 voltages **V1**, **V2**, **V3** and **V4**. When the set value change terminal SEL has a value at H level, the bias selection circuit 8 selects the bias voltages **V1** and **V4** for the input terminals **BP** and **BM**, respectively, and when the set value change terminal SEL has a value at L level, the bias selection circuit 8 selects the bias voltages **V2** and **V3** for the input terminals 20 **BP** and **BM**, respectively. In this case, the four bias voltages **V1**, **V2**, **V3** and **V4** are set to, for example, 1.25 V, 1.225 V, 1.175 V and 1.15V, respectively. Therefore, the offset voltage of the offset buffer 6 can be switched between 100 mV and 50 mV through the selection based on the set value change terminal SEL.

In this manner, the offset value for preventing the error detection of noise as a 25 signal can be selected in accordance with the quantity of noise caused in an employed application, and therefore, the degree of freedom in design can be increased.

In this embodiment, the reset signal **NRESET** is output to the data processing unit **100** when the number of transitions occurring in the predetermined time of the output signal **RSIG** of the offset buffer **6** of the signal detection unit **500** detected by the frequency detection circuit **5** is not more than the given set value, so as to control to reset the operation of the data processing unit **100**. Instead, in the same manner as described in Embodiments 1 and 2, in the case where the data processing unit **100** has a power down signal input terminal, a power down signal can be used as the signal from the frequency detection circuit **5** to the data processing unit **100**, so as to power-down control the operation of the data processing unit **100**.

Also, in order to control the operation of the data processing unit **100**, the output of the offset buffer **6** can be controlled, with the frequency detection circuit **5** removed from the signal detection unit **500**, so as to directly input, as a reset control signal, the output signal of the offset buffer **6** to the reset terminal **NR** of the 1:7 serial-parallel converter circuit **2**. Thus, the fail safe function can be realized merely by detecting the amplitude and there is no need to detect the number of transitions.

EMBODIMENT 4

FIG. 5 shows a receiver circuit according to Embodiment 4 of the invention.

This receiver circuit includes a data processing unit **100**, a clock signal processing unit **200**, a signal detection unit **500**, a resistor unit **600** and a resistor reference unit **700**.

This receiver circuit is different from that of Embodiment 3 shown in FIG. 4 in that the input signal input to the set value change terminal **SEL** of the bias selection circuit **8** is specifically an output signal output from the resistor reference unit **700**. The resistor reference unit **700** refers binary data stored in a specific bit of resistors of the resistor unit **600**, and a signal corresponding to the referred data is supplied to the set value change terminal **SEL**, so as to change the offset voltage value (set value) **Vth**. The data in the

resistors can be externally read and written, and hence, the address of a resistor in the resistor unit **600** can be specified by using software so as to rewrite the content of the specified resistor. In other words, the noise resistance can be selected by using software.

Also in this embodiment, in the same manner as described in Embodiments 1
5 through 3, in the case where the data processing unit **100** has a power down signal input terminal, a power down signal can be output as the output signal of the frequency detection circuit **5** instead of the reset signal, so as to control the operation of the data processing unit **100**.

Furthermore, as described in Embodiment 3, the frequency detection circuit **5** may
10 be removed from the signal detection unit **500** for controlling the operation of the data processing unit **100**.